THE STORY OF BLACK DIAMOND COAL

S. K. Pande

PUBLICATIONS DIVISION

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PUBLICATIONS DIVISION
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PREFACE

Originally, I have written this book in Hindi because I strongly feel that more and more books should be written in the mother-tongue of the reader. This would help them in better understanding of the subject which in turn encourage them to think and produce original work.

The Hindi book "KOYLE KEE KAHANI" has been published in mid 1999 by the Publications Division of the Government of India. Infact it is the only book on Indian coal written after a lapse of 40 year gap.

Therefore, this book is a reproduction of the original book in Hindi. Although, the title of the book is "The Story of Black Diamond-COAL", but while explaining as to how Coal was formed, the entire gamut of Earth's history is unfolded step by step before the reader - such as Big Bang and Origin of the Earth, Continental Drift and Plate Tectonics, Advent of Life - their evolutions and extinction, rise of the Himalayas and their seismic sensitivity, documentation parameters of earth's chronological history, importance of environment protection, origin of coal and its occurrences/quality/reserves/ mining methods/production, history of Indian Coal Mining Industry and its up-to-date status and in the end Indian energy scenario. Thus this book provides up-to-date data of the Indian coal industry.

In writing the book I have used very simple language. I hope it will interest young readers.

Purulia,
West Bengal.

S.K. Pande

FOREWORD

Coal, as a source of energy and chemicals, is one of the most valuable gifts of nature to mankind. Modern civilization is so much dependent on coal that despite the concern for greenhouse gases and global warming, the consumption of coal will continue to rise in the world in the foreseeable future. Shri S. K. Pande has attempted to present *The Story Of Black Diamond–Coal* in an interesting manner. Beginning with the origin of the universe, the solar system and the earth, he has discussed the chronological evolution of life on earth. The changing environment on earth resulted in luxurient growth of trees which fell down and accumulated in slowly sinking swamps on which more trees grew and fell, building up large thickness of submerged plant debris which were gradually converted to peat, to lignite and ultimately to coal. He has talked of the coal deposits of the world, the reserves in different coalfields of India, the properties and uses of coal and briefly the history of coal mining in India. Finally, he has discussed the energy scene in India and the role of coal in the years to come. The coverage is indeed quite comprehensive.

This book, I am sure, will whet the appetite of senior school students. I have great pleasure in commending this book to all those who are interested in the study of coal.

D.K. Paul
Director
Indian School of Mines
Dhanbad.

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INTRODUCTION

Coal is called Black Diamond, such is its glory. But why so? I will tell you the full story. Coal and diamond are natural resources found in earth. Chemically diamond is pure carbon, where as different types of coal contain 55 to 95 percent carbon.

Natural diamonds are of two types - Gem and Industrial variety. The word diamond is synonymous of gem variety which is mainly used as jewellery and commands a very high price in the market, often running into several thousands of rupees. As against it, the price of industrial diamond is insignificant - about Rs. 20 per carat (1 carat = 0.2 gms). Besides, diamond bearing rocks are found in few selected locations in the world.

Infact, to recover 2 tonnes of diamond, about 15 million tonnes of diamondiferrous rocks have to be mined and processed. But after taking this much of trouble to recover diamonds, the percentage of gem variety found in them is very small. In the famous Panna diamond mine of India, 100 tonnes of rocks yield 9-12 carats of diamond in which barely 20 percent is of gem variety - hence the high cost.

Gem variety diamond has brilliant splendour which has attracted human beings towards it. This attraction has in the past created new histories - the story of famous Indian diamond *Kohinoor* is well known. Even the poets are influenced by its sparkle and have compared the shining stars in the sky with diamond—*Like A Diamond In The Sky*.

On the other hand, coal is found in several countries of the world in huge quantity. It is important, not merely for the fact that it is an important energy source, but by processing it in different manner we get by-products, whose cumulative price is much more

than diamond. This is the reason, why, the black coal is glorified as *Black Diamond.*

Blessed by the nature, Coal came into existence. For ages it has been used as a valuable substance. Although coal is known to have come into existence many million years ago, the history of coal used by man is only few centuries old. In absence of authentic documents, scholars differ in their opinion as to when Indians started using coal. On one hand some scholars point out the words *angara, agni,* etc. Its reference in the *Rigveda* indicates that it is used since *Vedic* times, while the others connect it to charcoal because of the easy availability of jungle wood. However, it is agreed that Indians had the knowledge of coal since ancient times.

Many old prevalent names of coal in the coalfields in India such as *kalipahari* (black hillock), *angarpathara* (burning stone), *barakar* (big mine), *damodar* (fire in stomach), etc., suggest that the local people in these parts of India were aware of the presence of coal. Therefore, it appears logical that despite easy availability of fire wood, Indians were occasionally using coal since long time. Another reason for not using coal on large scale could be the abundance of animal waste and its use as a source of energy. Even today, India has the largest population of livestock in the world and animal waste is still used in Indian villages to meet the fuel and energy needs.

The credit of first worldwide use of coal can be attributed to the beginning of industrial revolution in 18th century. In order to meet the increasing demand of cloths to meet the needs of growing population in England, many superior designs of looms were developed between 1733 to 1785. This was the time when James Watt invented the steam engine in 1782. The immense potential of its wide application led to development of many industries in which big machines could be used both for high production and increased profit. Till this time charcoal was the main source of heat energy required for smelting iron ore. Thus, charcoal requirement increased many fold for steel making and manufacture big machines. Since the demand was more than the supply, the prices of charcoal moved up steeply paving the way for coal mining.

In the initial stages, the knowledge of immense heat potential in coal, encouraged its wide use in many industries. The invention of steam locomotive for running trains by Stephenson in 1814 provided permanency to the coal mining industry.

The gradual increase in the use of coal drew attention of scientists all over the world.towards coal research. By the advent of 20th centurey, knowledge of coal utilization in many spheres was known. Such a knowledge on one hand, provided a solid foundation to the coal mining industry and on the other hand, led to the efforts to locate and develop new coalfields. In India coal mining was started during British rule.

Coal is mainly used in producing electricity and steel products,many chemicals and fertilizers are the byproducts. Coal and iron together have been the basis for the development of industrial nations all over the world. Coal is important not only because of the fact that it burn and liberate heat, but also because it is an amazing organic substance which is also used for carbonization, gassification and conversation to oils and chemicals.

Nearly 200,000 by-products are made from coal-tar, and these products daily touch the lives of every one.

Coal is the most important source of Energy in India. Do you know, how it came into existence. In future also, no change expected in this pattern of sources of energy, except that share of natural gas is likely to increase, which will replace petroleum products.

CHRONOLOGICAL HISTORY OF EARTH

None has seen the process of coal formation, but all agree that the vegetation is its foundation.To understand modus-operandi of this information, Earth's chronological history is built by retrospection. Broadly speaking it is well known that coal is formed by the vegetable matter, but when, where and how this much have happened is not a common knowledge. To understand this the Earth's chronological history of development has to be reconstructed.

The age of the Earth is estimated around 4500 million years and within this period, the man has just appeared on the scene about one million years ago. Therefore, it is a very difficult task to reconstruct the unseen history of Earth.

However, the Human species is an intelligent being, who by virtue of endowed powers of observations, thinking and analysis has been continuously engaged in experimenting to find out the realities within his scientific understanding.

In the process, the scientists have reconstructed the chronological history of the Earth, which is based on contemporary scientific knowledge.Therefore, with passage of time, when authentic scientific facts or new data are known, the existing scientific thinking is modified accordingly.

Chronological history of the earth, is reconstructed today, by fossils embedded within rocks and radioactive decay. The chronological evolution of life on earth through time and space has been constructed on the basis of palaentological and radioactive studies.

The evolution of life has progressed in a gradual manner taking each step in a systematic order. The first life form, having

unit-cell appeared about 3000 million years ago and with the division of these cells, over a period of time, new life forms started appearing. The present form of lives that we see today is the result of long history of "life evolution cycle", spread over millions of year. The man has just appeared in the scene.

Fossils are the remains or imprints of different organisms preserved in the contemporary rocks and their study is called palaeontology. Now, since the evolution of life has followed progressive development, the fossils are also found embedded within rocks in similar chronological order-underdeveloped to developed. Therefore the palaentological study is an important tool to determine the age of the rock. Besides, it helps us to study change in life forms, evolution and branching-off of new groups through time and spaces (see evolution of Dinosaurs). It also guides us in reconstructing the climate of the period.

Dating of non-fossiliferours rocks is done by radioactive method, which is based on the principle of decay rates of some radioactive elements present in rocks.

The rate of decay of radioactive substance is known from experiments. For example, it is known experimentally that one gram of uranium decays to half gram in 4500 million years. This is known as half-life of uranium. So knowing the amount of decay it is possible to know the time taken to decay to a certain extent to the age.

There is another way by which age can be determined. Uranium is known to decay into thorium, then radium, and finally into lead. When one gram of uranium decays to half a gram in 4500 million years, 0.433 gram lead is produced as the ultimate stable products of uranium decay. So knowing the amount of lead formation in a rock, it is possible to determine the age.

ORIGIN OF THE EARTH

It is believed that to start with, there was nothing, not even an empty space, what to talk of other things. Big Bang, the most accepted theory of galaxy creation, accounts for space, time, energy and matter creation.The beginning of everything was about 10,000 million years ago, when the universe was a single point concentrated primeval atom. This exploded into discrete galaxies and other condensed matter. These continue to move away from each other in the expanding universe at ever increasing speed approaching the speed of light to finally disappear.

Our Galaxy, the Milky Way, is made up of 100,000 million stars grouped in a huge spiral measuring about 100,000 light years from the edge (one light year is the distance light travels in a year at the speed of 300,000 Kms per second). Beyond our Milky Way lie millions of other galaxies.

Primitive Sun was surrounded by dust and gaseous substance. Their collision and coalescence culminated earth's emergence. The embryonic earth was born 4,600 million years ago by the collision and coalescence of the cloud of dust and gas surrounding the sun. Compaction under the influence of gravity coupled with radioactive heat led to the melting of iron that sank to form inner core; The buoyant silicates and oxides migrated to form the outer layers—still in liquid form. Slowly, these outer layers, the mantle and crust, solidified.The atmosphere developed from gases released from the rocks by volcanic action.Water vapour condensed and fell as rain—the beginning of the formation of oceans.

In the vastness of space, our *Solar System* is a mere speck, lying at the outskirts, about two thirds way from the galactic centre.

Sun plays a dominant role in this system. A family of nine

planets and thirty three satellites, asteroids, meteoroids and comets of different shapes, size, appearance and temperature revolve round the sun.

The Sun is a medium sized star and is one among millions of stars that make up our Galaxy - the Milky Way.

The earth is third from the Sun and the fifth largest in our solar system and is the only planet where life is known to exist. The Moon is the only satellite of the earth.

DRIFTING CONTINENTS

In distant past, at the time of the origin of the earth, all continents were held together in a circular girth. This was a big mass of land named Pangaea. Wegener was one, who gave idea of this name around 1912-1922. The Earth's crust has been continuously changing since its inception. The present day distribution of land and oceans have not remained static, but has undergone changes from about 200 million years ago.

It broke into different continents and drifted apart in different direction to achieve the present configuration.

In "Mesozoic Era" this big mass broke into two blocks,Lauraisa and Gondwana and Pangaea was encircled by sea in all direction. The outline of Pangaea was somewhat unusual and it was partially divided by Tethys sea having extended arms like triangular shape.

Some 200 million years ago Pangaea started breaking. At first the division took place at the apex point of Tethys sea where Pangaea was narrow and it was divided into two named Laurasia and Gondwana and North America, Europe and major parts of Asia became part of Laurasia in the north. Whereas Arabia, South America, Africa, India, Australia and Antarctica formed Gondwana land in the south.

The Laurasia block drifted towards the north side, the Gondwana block remained in the southern side.

Thereafter—

(1) 180 m years ago Gondwana land broke into three parts - South America/Africa, Antarctica/Australia and India.

(2) 135 m years ago South Atlantic Ocean began spreading between South America and Africa. At the same time India

started drifting with extraordinary speed towards Asia and about 30 m. years ago joined with it giving rise to Himalayas.

(3) 45 m years ago Antarctica and Australia were separated.

(4) 35 m years ago North America and Europe separated.

(5) These separated continents drifted slowly to occupy the present position.

With time-lag, these blocks broke into pieces and drifted apart, subsequently establishing today's continents by these parts.Since the beginning, our continents have not stopped drifting, it still continues and their positions are still shifting.This drifting of continents is directed towards north side, excepting Antarctica, all continents are having northern slide. During this long journey, which began from Pangaea, except Antarctica all other continents have been drifting, slowly towards north and have also experienced different amount of rotation as well.

To start with, other scientists did not accept this idea. Earth is immovable they thought. How to accept this idea! They could not understand as to how drifting could take place. Till 19th century the scientists were of the opinion that the earth's land mass was immovable in horizontal manner and continents have remained at the place of their birth. Similarly, the ocean floors are also equally permanent and since they are always submerged in water, they do not suffer any change on account of varying season. The job of ocean floor was only to collect and store the drifted land-debris.

In 1929, one British geologist, Arthur Holmes suggested that despite earth's top cover remaining solid, it is not immovable and probably by moving forward has been drifting for a long time. According to Holmes, if the outer cover of the earth crust contains energy-source, such as heat, then convection current can help the continents in drifting.

When, this also could not convince the scientific community, then Holmes put forward further solution to resolve this issue and suggested that mountains emerge at a place where drifting continents exert pressure on seafloor. He also asserted that on account of excessive heat and pressure the density of rocks increases and

they are pushed down of their own within earth's interior. By this process, the present day continents have drifted with slow speed from the original pangaea. These revolutionary thoughts generated some animated discussions within the scientific world, but did not meet their acceptance.

PLATE-TECTONICS THEORY

During nineteen fifties, a new capacity was acquired by scien tists. Measuring pole orientation within rocks of different ages of displayed shifting in rocks, scientists began to understand the drifting theory. Thus was born, now accepted plate-tectonics theory. However, around 1950, data from unexpected sources started pouring-in and the attention of the scientists was once again drawn towards the principles suggested by Wegner, Holmes and others. By this time scientists had acquired capacity of measuring smallest amount of magnetism within the rocks. Whenever a new rock is formed, the magnetic parts within it are oriented in the direction of the magnetic poles of the period. In this way, when scientists measured rocks of different ages, it came to their notice that with lapse of time, orientation of the poles have been changing and this shift has been wandering all around the globe and this phenomenon has been named "Polar Wander Curve". By measuring polar wander curve for different continents, it was seen that they are not similar. Now since, north magnetic pole at one time will remain in one direction only, opposite wandering direction between two continents, clearly indicates that in past these continents have undergone relative drifting. This knowledge by 1970, culminated into the principles of "Plate Tectonics", which is now widely accepted.

In this, the drifting continents have been replaced by drifting "Continental and Oceanic Plates" and these plates have been identified.

Platetectonic says, twelve plates constitute the earth.Collision of drifting plates produces new environment on earth, At some places starts mountain building activity, at other volcanoes erupt or start earthquake activity. The Earth's crust is discontinuous - made

of at least twelve closely fitting continental and oceanic 'Plates' which are in differential motion with respect to each other and the Earth's axis. All prominent geologic and tectonic activities - volcanoes, earthquakes, mountain building, etc. are localized around the plate margins.

It is not that only continents are drifting. The ocean-floors are also active and they perform the function of prime-mover in drifting of continents. All main oceans, within them have a very long chain of high mountains which are connected with each other. The length of these mountains is about 80,000 kilometres and at places they have attained 3 km. height. Although, they have been named separately, they have one similarity that they are joined along a narrow strip following their axis through which hot molten magma from the earth's interior pours out from time to time. This magma, on reaching surface solidifies after cooling and is spread over the sides of these mountains. Therefore, the ocean floor is in continuous making and spreading.

Now the rule is that, since the lithosphere of the continents is lighter than the ocean's lithosphere, the continents will remain at top. Now assuming that the earth can neither shrink nor reduce, this continuous increase and spread of ocean lithosphere has to be destroyed. This work is carried out within a narrow area called "subduction zone" where the expanding lithosphere, bending downward, enters the earth's interior and gradually liquefies to become a part of magma. This subduction zone is like a long narrow trench which at places can accommodate water upto depth of 10 km. Therefore, at a place, where two expanding sea floors meet, a reduction takes place in the floor having comparatively less resistance. Similarly the reducing ocean floor below the bottom part of a continent edge, pushes that land mass towards the subduction zone and then encounter takes place between land masses. Now since none of these land masses can suffer reduction, they try to climb over each other, giving rise to mountains. Thus Himalayas have appeared in the scene when India collided with Asia. The Himalayas still continue to rise, since India is constantly trying to push itself below Asian plate.

Africa, which has always remained close to Eurasia (Europe and Asia) has been drifting for sometime towards north in relation to Eurasia. In the north it has already joined with its neighbour - the Middle East and is pushing itself to join with Spain. In the process the Mediterranean Sea is shrinking in size and after a lapse of few million years may cease to exist.

However, the most classic example of continents collision is provided by India which has already joined with Asia. India has travelled at an astonishing speed of 17 cm per year after it broke away from Gondwana land, whereas the speed of drifting by other continents ranged between 0 to 7 cm.

According to present estimates India continues to drift in north direction at a speed of 2.5 cms per year. On account of this pressure the Himalayas continue to rise and simultaneously compressed energy is being stored within Himalayan rocks. Now since these rocks are strong enough and can withstand considerable pressure, they do not break immediately. However when at any place it crosses the limit of their storing capacity, the compressed energy bursts out in form of earthquake. This forward drifting process is intermittent and therefore the compressed energy is also stored accordingly. Once an earthquake erupts at one place, the compressed energy is stored in a different place and under similar condition, as described above, earthquake erupts at this new place. This process is continuing in Himalayan region since last 30 to 40 million years and may continue for many more million of years.

Therefore the entire Himalayan region is very sensitive to earthquakes and in a year it experiences, on average, about 625 small and medium scale earthquakes. During last one hundred years it has experienced six major earthquakes.

EVOLUTION OF LIFE ON EARTH

About four and half billion years ago the earth was born. Three billion years ago environment was developed for life form. Initially life appeared in underdeveloped, primitive state. There was neither man nor animals, nor vegetation at this stage. At the start of life, the first oceans were still only few degrees below boiling point. The ultraviolet rays from space and lightning from thunder storms playing with hot water of oceans produced first building blocks for life, i.e., amino and nucleic acids. The process has been repeated many times and in many places in the universe. Amino acids floating between the stars has been recorded by the astronomers, but in earth it gave rise to a history of life which may be unique in its extraordinary variety and abundance.

There are 4.6 million different types of life forms alive today, and perhaps double the number were alive in the past, but are extinct today. The foundation of all these life form started with above basic building blocks and yet everyone is unique. That is the double miracle of evaluation - the flow of genetic information across the ages and the editing of that information into almost countless separate categories. The editor in this case is environment which has allowed the survival of the fittest in particular environment niche and totally destroy others who cannot make use of the resources around them.

Earth came into existence 450 million years ago and within this man has just appeared in the scene, about one million years ago. Therefore, there is no question of our ancestors witnessing the birth of earth and its subsequent development. Thus to recreate such difficult history, scientist depend upon, the well known saying that "the present is the key to the past."

In our life time, we are witness to the different kinds of natural and man made activities in the world such as earthquakes, volcanic eruptions, rain, lightning, thunder, cyclones, floods, landslides, glaciation, meteoritic fall, war, destruction, nuclear tests and leakages, deforestation, etc. and we can study and evaluate their impact. These observations coupled with the current scientific knowledge help the scientist to recreate the chronological history of the events on earth since inception. However, our scientific knowledge is also continuously improving with passage of time and therefore when some new scientific data emerges, views on the subjects also change. This process will continue in future as well, for we would have acquired more scientific knowledge, for example-

The scientists of National Aeronautics and Space Administration (NASA) said in a statement on 7.8.96 that in a meteorite sample of Mars which fell on the Earth few thousand years back in Antarctica, they have found traces of organic matter and fossil-like structure which could have been produced by ancient microorganisms, showing the possibility that "primitive form of microscopic life may have existed on mars over 3.6 billion years ago". It is a startling discovery and if substantiated by further concrete evidences, it would revolutionize our present thinking about evolution of life in our solar system.

The question has always existed that , "Is life on earth unique?" A discovery of life on Mars, even primitive life in distant past would have profound intellectual implications.

It would raise the questions as to whether the life originated independently on the Earth and the Mars, or started first on one planet and then migrated to the other, or perhaps migrated from somewhere else entirely.

If life evolved independently on two separate planets in our own small solar system, there is the likelihood of its presence elsewhere in the universe also.

Although the above stated report of NASA has created sensation in the scientific circle, many scientists have disagreed with their conclusions. They are of the opinion that the evidences put forward

in support by NASA, could be the result by non-biological process as well. Therefore more conclusive evidence, to confirm scientific parameters is required, to establish that life existed in Mars.

Life forms have also been changing, keeping pace with the development activity on earth where old is replaced by new. Evolution being eternal process of change, simple life forms are subsequently seen to adopt complex life forms. This process helps the life forms to gradually go on adjusting with the ever changing environment and adopt an altered form most suitable under the new conditions available to it.

However, these modifications and adoptions are carried out over considerable length of time, during which new life forms continuously appear, which are adapt to survive in the existing changed environment.

These newly evolved forms, although performing different functions are interlinked with each other by mutually beneficial activities. Plants for example are the main source of food supply, but they also function to maintain the correct mixture of gases in the atmosphere, so essential for other life forms including human beings. Even small creatures like insects make their contribution as a clearing agent of the refuse material from the earth's surface by eating dead animals and plants. By this process they accelerate their decay and thus release the nutrients locked up in dead bodies for recycling which ultimately helps in growth of plant life.

This type of interdependence on each other unifies the life forms in a pool of life, but the biggest unifier is DNA or the genetic code of life. DNA is present in all life forms and has the capability to transfer hereditary characteristics in the new generation of life forms. Although new life forms inherit hereditary characteristics, some variance is established between the members of the same group. These variations form the basics of genetic diversity.

In the natural eco-system, the life cycle continues to flourish in above manner, but slightest of unnatural activity in-between, breaks the link of evolution chain, which in turn influences the development of life forms and many life species are forced to

extinction. In this world many life species are already extinct, before they were discovered.

The extinction of one plant species affects 10 to 30 other species dependent on it including insects and animals. Extinction is a natural process, active from the time life began in this world, where old forms give way for the new forms. Extinction in a natural way is also a great loss, but when it happens on account of unnatural/artificial circumstances the loss is irreparable. It happens with such a speed that the alternate developing life forms do not get sufficient time to adjust to the changing environs. However, species generally become rare, before they extinct. Here lies the importance of conservation - given protection in time, they can survive.

Dinosaurs is one such example of extinction. Dinosaurs had attained huge body structure and by virtue of worldwide distribution had the earth under their sway for more than 120 million years, just like man dominating the scene today by virtue of intelligence. Then all of a sudden, about 65 million years ago they disappeared from the scene leaving a big question mark - as to why, what for and where to. Scientist differ in explaining their extinction, but they take recourse to changing environment as the cause, paucity of food, lethal cosmic rays emitted from the explosion of a super nova, meteoritic impact etc.

By the time dinosaurs became extinct, mammals had appeared on earth. Thereafter man appeared about a million year ago and since then man and mammals are performing major role on earth.

The story of dinosaurs provides clear indications that for continuance of life, natural undisturbed environment is a prerequisite. Man cannot live alone since the history of evolution of life shows that the best way to survive on earth is by maintaining timely adjustments and balance with nature.

Our biosphere has about 3.5 million floral and 1.1. Million faunal species, and among these, man is the only intelligent species. Therefore, the welfare of the earth's environment lies entirely on the shoulders of man.

Man has to provide full protection to the remaining biodiversity in the earth, to secure his future.

BEGINNING OF PLANT LIFE

Life began with algae, and later appeared plants and trees on earth. Evolution of plants and trees culminated in birth of coal on earth.Luxuriant vegetation grew and spread wherever favourable nourishing climate was available. Although first plant life appeared on earth in Silurian, it started taking shape of forests in Middle Devonian. From Carboniferous time onwards conditions became very favourable for luxuriant growth of forests.

During these pre-historic times, large densely forested swamps existed in many parts of the world including the Indian subcontinent. The environmental and climatic conditions during these times were very favourable for the prolific and fast growth of vegetation. In such swamps huge forest grew and when the trees fell down, they got accumulated in the swamps itself, over which fresh trees grew again. During their period the bottom of the swamps or basins was undergoing a process of slow and steady subsidence.The slow sinking of the swamp floor resulted in building up of large thickness, often upto hundreds of feet of submerged plant debris, which underwent bacterial decay and decomposition. Such bacterial decomposition of the plant debris is the process by which wood and vegetable matter were converted to peat and ultimately to coal.

It is estimated that about 10 feet of plant remains is required to form one foot of peat and about 12 feet deposit of peat is required to make one foot layer of coal, which means that about 120 feet of plant material will produce one foot of coal.

Presence of thick coal seams (layers) are known in many coalfields of the world. Some Indian examples are—

Coal Field	Coal Seam		Estimated Requirement of Plant Debris
	Name	Thickness	
Singrauli	Jhingurda	250 ft.	30,000 ft.
East Bokaro	Kargali	150ft.	18,000 ft.
Raniganj	Salanpur	150 ft.	18,000 ft.
Jharia	V / VI / VII	100 ft.	12,000 ft.

Note : 1 metre = 3.2 feet

On the basis of the above data, we can think of the prevailing environment conditions of the time when coal formations were deposited in the world.

This process repeated time and again for many million years.Trees grew, fell down and got buried in basins during these years.Subsequently, after perhaps hundred of years of such slow sinking of the swamp floor and consequent accumulation of plant debris, the rate of sinking may have speeded up suddenly submerging entire forests. Into this depressions so formed, the rivers and nullahs brought and deposited mud and other sediments over the plant debris and forest below. Such sediments gave rise to shales and sandstones of today.

The rate of sinking again slowed down after sometime and the sediments could again support fresh forests.This cycle of slow and rapid subsidence repeated itself during thousands of years, giving rise to successive layers of plant debris and other sedimentary deposits of different thickness. These deposits were subjected to compression and heat due to earth movements and other geological causes and in course of time got converted into layers of coal, shales, sandstone etc. This oscipating cycle is responsible for the presence of different coal seams with varying thickness at irregular intervals separated by these other rock types in the coalfields.

To start with, the plant debris consisting of lignin, protein and resin underwent transformation into a porous, fibrous and friable mass called 'Peat' by the activity of micro-organisms which thrived in swampy environment.This process is called humification and all coals are believed to have gone through it.

Under the blanketing of new strata, with pressure and earth movements, peat got converted to lignite. With more pressure and rising temperatures, resulting in progressive dewatering, loss of carbon-dioxide, hydrogen, methane and amalgamation of acidic and basic humid bodies, lignite gave place to bituminous coal and finally, under the influence of intensive earth movements, to anthracite.

No one has seen the plants turning into coal, but we do find conditions existing even today, be it the dismal swamps of Virginia, the everglades of Florida, the swamps of Indonesia or nearer home in the Gangetic delta, akin to what must have happened in the bygone ages. We can observe today in the shallow lakes and basins and sluggish deltas of larger river systems like the Mississippi, the Amazon, the Ganges and the Brahmputra how 'life' turns into 'matter' and how 'matter' in turn feeds life only to turn it again into 'matter'. We can observe the swamps of yesterday growing as peat and we can watch how a change in environs can make it disappear over large tracts and find out why.

Though it is universally agreed that all varieties of coal originated from vegetal matter, there is a wide divergence of opinion regarding the mode of accumulation of these plant remains in the swampy basins to give rise of coal seams. Two opposite views with evidences in support of both have been put forward, one called the "in-situ" theory and the other "drift" theory. The former suggests an in-situ origin meaning that the vegetation grew at the same place, where we find coal today. Whereas the later holds that the vegetal matter have been transported by water from the original site of growth to the present site of coal seams. However, it is now accepted that coal seams of Western Europe and North America are of in-situ origin, while coals of India, Australia and many other countries are of drift origin.

TYPES OF COAL

Four types of coal found inside the mother earth are defined as peat, lignite, bituminous and anthracite. Coal is of vegetal origin and it is assumed that its evolution follows a continuous change from peat to lignite to bituminous which ultimately transforms into anthracite series. There is, however, less agreement on how the vegetable matter has been changed either into peat, lignite, bituminous coal and anthracite, and whether each of these named constitutes a unique product of evolution itself, or whether they all constitute rungs of a ladder in an evolutionary 'series'. In the later concept, which is the more accepted one, it has been tactically assumed that the metamorphosis of vegetal debris to anthracite is well-ordered, pre-destined and continuous change varying only in degree, depending upon geological history. The variations observed are then mainly the results of arrested development, like chapters in a 'serial' whose actors are known and their acts are fixed and follow and destined course.

Peat

In true sense peat is not coal, but is the first stage of coal formation, where vegetable matter is only partially decayed and accumulated.

It is light brown in colour and remains of the original vegetal matter are distinctly seen. It contains 90% water and 10% organic dispersed phase.

This first phase of development activity can be observed even today in many parts of the world, specially in the swamps and deltas of major river systems. In India it can be seen at the mouth of Ganges and Brahmputra rivers spread over entire Sunderban area.

In recent years, during excavation work for “Calcutta Metro”, peat beds of varying thickness were encountered 10 to 15 feet below ground at several places. This leads us to a conclusion that in distant past Calcutta was also like Sunderban of today.

Peat is not an economic fuel and is mostly used as a fertilizer because of its rich nitrogen content but some times it is used as an energy source in the form of balls.

Best known occurrence of peat in India is in the Gangetic delta. In South India peat is found in the lakes of Nilgiri Hills.

Lignite

It represents second stage of coal formation. It is brownish black in colour and hence called “Brown Coal” also. It is composed of woody matter embedded in macerated and decomposed vegetal matter which is banded and jointed. It slacks and disintegrates after drying in air. It contains 25% to 45% water and 55% to 75% combustible matter. If peat is left at its place of origin, it would gradually turn into lignite after a lapse of time.

Although it is more solid than peat, the remains of original vegetal matter can be identified to some extent. It slacks and disintegrates on exposure to the atmosphere and is likely to ignite spontaneously, as it readily absorb oxygen and therefore its storage and long distance transportation has problems. This necessiates its pit-head utilization. Lignite is used for thermal power generation, briquetting and fertilizers.

Germany is the largest producer of lignite in the world, where lignite based power plants have been constructed near the mine site. In India also, similar practice is followed by the Neyveli Lignite Corporation in Tamil Nadu.

In India lignite is found in Pondicherry, Tamil Nadu, Gujarat, Rajasthan and Jammu and Kashmir state. Besides, sporadic occurrence have been reported in Kerala, Maharashtra and in certain parts of Assam.

In recent years large deposits of lignite (18,000 million tonnes estimated at the start of 1994) have been located in course of

exploration around Mannargudi in Quide Milleth district of Tamil Nadu, spread over in 400 square kilometre area. Investigation work is in progress and with its completion more reserves are likely to be added to the quantity already known.

As per estimates of the year 2000, India has 30,300 million tonnes of lignite reserves.

In contrast to the prolific development of bituminous coal in India, the lignite reserves are insignificant. However, when we see their regional distribution, we find that bituminous coal is confined to South-Eastern Quadrant and the lignite deposits, though small in nature (except in Tamil Nadu) are spread over Kashmir, Rajasthan, Gujarat, Kerala, Maharashtra and Pondichery. This separate identity of lignite occurrence, away from the major coalfields of India have great regional significance.

Bituminous Coal

It is the most important member of the coal family and occupies third stage in coalification series. When lignite is buried deep within earth, it is gradually converted into bituminous coal under the influence of heat, pressure and biochemical changes in due course of time.

It is black in colour, dense dark, brittle, banded coal that is well jointed and breaks into cubical or prismatic blocs. It does not usually disintigrate on exposure to the atmosphere and therefore can be transported to long distances for its use. The original vegetal matter is not ordinarily visible.

It ignites readily and burns with smoky yellow flame. It generates considerably more heat than lignite. On account of its world wide distribution and large reserves, it is most extensively mined (1991 world production - 3641 million tonnes) and is used as solid fuel in the world.

All bituminous coals are not alike. They are subdivided into number of varieties depending upon their properties which determine their use. Most of the Indian coal are of bituminous type.

Anthracite

Deeply buried bituminous coal within earth, under favourable conditions of pressure and temperature, is converted to anthracite after a lapse of time.

It is hard coal with jet black shining colour. It is brittle and breaks with conchoidal fracture. Its outer surface shines like glass and it does not soil the finger. It does not disintigrate and therefore can be transported to long distances without difficulty.

It takes time to burn and the ignition takes place with slow speed. It burns for a longer time than bituminous coal.

True anthracite are very rare in India. Some anthracite are found in Kashmir, Darjeeling and Sikkim. A variety of anthracite called "Semi-anthracite" was mined in central part of Rajhara colliery of Daltonganj coalfield in Jharkhand, but these reserves are now exhausted.

Anthracite is used for metallurgical purposes, steam raising and slow combustion stoves.

In the Coalification series, during the transformation of peat to anthracite, the greatest single change observed is the change in ratio of quantity of water, which gradually reduces and combustible matter which gradually increases. Peat for instance, consists of 900 parts of water and only 100 parts of combustible matter, per 1000 parts of peat. On the other hand, in the high rank bituminous coals, out of 1000 parts, only 20 parts are water and 980 are combustible matter.

ANALYSIS OF COAL

Coal properties determine its proper usage. Many tests are conducted to decide usage.On account of different physical and chemical properties, all coal cannot be used for all purposes. This has warranted suitable classifications, nomenclatures and testing procedures to identify specific usage of coal.

Broadly speaking, coals are categorized as non-coking and coking.

COKING

The coking coals are those, which on heating upto 925°C in total absence of air, first melt and then produce a cake like mass on full carbonization.

This cake like mass is called Coke. Its end use in metallurgical industry depends upon the specific quality parametres of this cake.

NON-COKING

All those coal which on heating crumble and do not form cake like mass are called non-coking. These coals are used in power, cement, sponge iron, domestic and other sectors depending upon its ash content.

ASH

The residual non-combustible material left after complete combustion of coal is called ash.

The broad parametre for the end use of coal in various major industries based on ash content is given below:—

Type	Sector	Ash content
Coking	Steel	17 - 18%
Non-Coking	Power	34 - 35%
	Cement	26 - 28%
	Sponge iron	25%
	Coal dust injection	15%
	(corex process)	20 - 25%

The amount of ash and its composition have important bearing on the end use of coal. With the increasing quantity of ash, the heating value of coal decreases, reducing thereby its commercial value. The mineral constituents in the ash determine the behavior of ash in furnaces, be it thermal plant boiler or a blast furnace for iron smelting.

When heated, the coal ash does not melt sharply at any definite temperature, but commences to soften at substantially lower temperatures than at which it becomes molten.

To reduce ash content, coal washing is carried out to meet the specific industry needs.

The broad characteristics of various ranks of coal are given in the table.

Broad Characteristics of Various Ranks of Coal

Rank	Specific Gravity	Water Content (%)	Fixed Carbon (%)	Volatile Matter (%)	Calorific Value (K. Cal/kg)	Vitrinite Reflectance (Ro%)
Anthracite	1.4-1.8	Roughly 3	92 - 98	2 - 8	7000 - 8000	2.5 - 2.6
Semi Anthracite	-	3 - 5	86 - 92	8 - 14	8350	1.9 - 2.5
Bituminous	1.2 - 1.5	3 - 15	46 - 86	25 - 40	6500 - 7500	0.6 - 1.9
Sub Bituminous	1.2 - 1.4	15 - 25	37 - 45	33 - 50	3500 - 6500	0.4 - 0.6
Lignite	1.1 - 1.3	20 - 50	27 - 31	25 - 55	2000 - 4000	<o.4

COAL DEPOSITS

Coal deposits do not occur everywhere in our world, but found in specific locations and time period.

World Coal Deposits

Geological Period	Percent
Tertiary	55.0
Cretaceous	small
Jurassic	4.0
Triassic	0.5
Permian	17.0
Upper and Middle Carboniferous	22.0
Lower Carboniferous	1.5
Devonian	small

Land plants first appeared in Silurian period, but they became abundant only during and after the Middle Devonian period. That is why, coal deposits have been identified in all geological periods since the Devonian.

The rank of coal (i.e., degree of coalification) tends to increase with the age of the deposits. Most lignites are of Tertiary age, but some also occur in Cretaceous rocks.

Mainly deposited in India during Gondwana period, it has also some occurrences of the Tertiary period.Jharkhand, West Bengal, Orissa, Chhattisgarh, Madhya Pradesh have main deposits, along with the Maharashtra and Andhra Pradesh coal deposits.Jammu, Arunachal, Meghalaya and Assam also have its trace,where many small coal deposits are found to show its

face.India's total land area is 329 million hectares and within this only 0.45% area is covered by coalfields, which belong to Gondwana and Tertiary periods.

Distribution of Coal and Lignite in India

Geological Age	Geological Formation / Group	Occurrence of Coal and Lignite
Tertiary		
Pleistocene	Karewas	Kashmir Lignite
Upper Miocene to Pliocene	Cuddalore bed	Lignites of Tamil Nadu
Oligocene	Tikak Parbat of Brail Group	Coals of Upper Assam, Arunachal Pradesh and Nagaland
Eocene	Laki and Jaintia Group	Lignites of Rajasthan and Gujarat, Coals of Jammu, Lower Assam and Meghalaya
	Kalol and Kadi	Coals of Cambay Basin, Gujarat
Gondwana		
Mesozoic		
Lower Cretaceous	Umia stage, Jabalpur	Thin coal seams of Gujarat
Lower Jurassic	Kota and Chikiala	Thin coal seams of Godavari and Satpura
Palaeozoic		
Upper Permian	Raniganj formations and its equivalent	Lower Gondwana coalfields of Peninsular India and
Middle Permian	Barren Measures	foot-hill regions of Eastern Himalayas.
Lower Permian	Barakar Formation Karharbari Formation	

Coal deposits of India are by and large confined to the southeastern quadrant of peninsular area, which is called "Golden

Triangle", for besides coal this region also contains India's major mineral wealth like diamond, gemstones, copper, manganese, tungsten, bauxite, iron-ore, mica, nickel, limestone, graphite, etc. The remaining three-fourth of India is devoid of important coal deposits.

Workable coals of practically all ranks occur in India except peat and anthracite. The share of lignite, however, is insignificant as compared to sub-bituminous/bituminous coal. But in Indian context, these small lignite deposits have significant regional importance because of their locational spread in states where no bituminous coal deposits are found.

In India, mineable coal deposits are found in two geological formations - Lower Gondwana formations of Permian age and Tertiary coals of Eocene and Pliocene age. However, the most important coal deposits are those of Gondwana formations, which account for 95.5% of coal reserves of India.

The coalfields of Jharkhand, Orissa, Chhattisgarh, Madhya Pradesh, West Bengal, Andhra Pradesh and Maharashtra are the main source of bituminous coal. However, coking variety is mainly found in the coalfields of Bihar and West Bengal. Few locations in Madhya Pradesh also contain coking coal.

The tertiary coal deposits are mainly located in Assam, Meghalaya, Arunachal Pradesh and Nagaland. In this North-eastern part of India, as many as 67 small and medium size coalfields are located in which both coking and non-coking bituminous coal is found. Compared to Gondwana coals, the Tertiary coals have low ash content, but the coking coals of this region have high sulphur content (upto 7%) and therefore cannot be directly used for metallurgical purposes.

COAL RESERVES IN INDIA

Indian coal reserves are about two hundred billion tonnes. further exploration may contribute one hundred billion tonnes.As per estimates of 1.1.2002, the total Indian Coal reserves are about 234 billion tonnes upto 1200 metre depth and they constitute 1% of the world resources. However, three-fourth of the Indian coal reserves are confined within 600 metre depth. Another 100 billion tonnes of coal reserves are likely to be added to this by exploration in near future.

Quality Wise Reserve Upto 600 Metre Depth (Billion Tonnes)

	Non Coking		Coking	
Superior Grade Ash % Upto 24	**Inferior Grade Ash % 24 - 50**	**Total Ash % Upto 50**	**Ash % Upto 35**	**Grand Total**
23.80 13.70%	126.36 72.70%	150.16 86.40%	23.62 13.60%	173.78 100.00%

Coal is a gift of nature and therefore its physical and chemical properties are also the product of nature. Indian coals have high ash content compared to contemporary coal deposits elsewhere in the world and they have difficult washing characteristics as well. Besides within one coalfied itself, the coal seams display different quality at depth and with lateral disposition. It is also seen that coking and non-coking coal are found in the same coalfield or display coking and non-coking characteristics in different part within a coalfield.

Coal Reserves of India (1.1.2000)

[Each Box = 10 thousand million Tonnes]

Gondwana		%
Bihar	69128	33
Orissa	50449	24
M.P.	43493	20.5
West Bengal	25910	13
Andhara Pradesh	13587	5.5
Maharashtra	7077	3
Uttar Pradesh	1062	0.5
Tertiary		
North-East Region (Meghalaya, Assam, Arunanchal Pradesh, Nagaland)	890	0.5
Grand Total - 2,11,596 million tonnes		100

Coal Reserves (All Rank)

Sl.No.	Country	In Billion tonnes	Percent
1.	China	6000	32.9
2.	Former USSR	5926	32.5
3.	USA	3600	19.7
4.	Australia	780	4.3
5.	Canada	474	2.6
6.	Germany	295	1.6
7.	India	198	1.1
8.	Poland	184	1.0
9.	UK	150	0.8
10.	Others	632	3.5
		Total→ 18,239	100.00

Eighty five percent of Indian Coal is non-coking and 15% is coking variety (suitable for metallurgical industry).

Indian Coal Reserve Upto 1200 m Depth (1.1.2000)

Type	Reserves	
Coking	31812.17	million tonnes
Non-coking	2,01,395.16	million tonnes
North-eastern region	906.95	million tonnes
Total	234114.28	million tonnes

There are about 2100 coal basins throughout the world with individual potentiality ranging from 500 billion tonnes to less than 50 million tonnes. The total estimated coal reserves of the world are around 30 trillion tonnes, of which 15 trillion tonnes are better known. As per World Coal assessment of 1982 and subsequent updation has brought the total reserves to the tune of 18,239 billion tonnes.

COAL MINING METHODS

Coal mining is carried out in two different ways, one is opencast and the other underground way. The choice of their selection depends upon their depth, thickness and inclination of the coal seams.

Opencast

When coal seams are at surface or near the surface and where the overlying rocks (shales, sandstone, limestone, etc.) can be economically removed and disposed off, opencast method is applied. In other words, opencast method is practiced at a place where the cost of removal of overlying rocks is less than the total mineable coal below them. In this method overlying non-coal rocks are first removed and coal seam is exposed. Thereafter coal mined separately.

By this method more than 80% coal seam is mined out and it is the safest method of coal mining. It is highly productive method when mechanization is introduced. In India, highly mechanized opencast coal mines comparable to world standard are operating in which 8 to 10 million tonnes of coal is produced annually, e.g. Jayant, Dudhichua, Gevra, Rajmahal, Piparwar, etc.

Underground

Where coal seams are at greater depth and removal of overburden (i.e., overlying rocks) is uneconomical, underground mining is carried out. In other words, underground mining is taken up in an area where the total cost of removal of overlying rocks is more than the total cost of coal that could be mined below it.

In this method a pair of incline or vertical shaft (like well) of

4 to 8 metre diameter are dug to reach the coal seams and from this meeting point the actual coal mining starts by entering the coal seams for which two major systems are adopted. They are - Board and Pillar and Longwall.

In the Board and Pillar system, there are 4 to 4.5 metre wide and upto 3 metre high galleries at right angles to each other. Leaving between them, 15 metre to 45 metre square coal pillars are dug within the coal seams. The size of these pillars depends upon the depth of the coal seams. The coal production starts with the development of this activity within the coal seams. Later on these pillars are also subdivided and coal is extracted. However, for safety reasons, a portion is left in pillars, roof and floor of the seam.

In Longwall system 100 m to 250 m coal faces between two parallel roadways are opened up within the coal seams where intensive mechanization is adopted to produce high quantity of coal. All over the world, this is the most extensively used system of coal mining, but in India about 95% of underground coal production is still obtained by Board and Pillar system.

There are a number of other special methods designed for underground coal mining as the situation of thick seams, highly inclined seams etc. demand.

However, in hilly area, horizontal adits are driven to reach the coal seams for starting mining operation.

Besides, many other precautionary measures are required to be taken for the safety of men and material in underground mining, specially in respect of methane gas which is highly explosive. Vegetable decomposition at the time of coalification is believed to be mainly responsible for the formation of methane and other gases such as CO_2, O_2, H_2, CO, N_2. As coal matures these gases (share of methane is proportionally large compared to others) are trapped in the fractures of coal and the pressure exerted by naturally formed water keeps them "absorbed" on internal surfaces of coal. Therefore, all coalfields in the world have coalbed methane. The only difference being the quantity of gas in each coal seam. Thus, in order to provide safe underground working conditions, arrangements for

fresh air circulation are made underground by installing ventilation fans and in the coal deposits which are likely to emit gas beyond a specific limit flameproof electric machines/equipments are used.

Now since, underground mining is like digging many deepwells, arrangements are made for dewatering of the mine area through installation of heavy duty pumps and laying pipe lines.

Similarly for prevention of fire and explosion, adequate mining ventilation through induction of fresh air and stone dusting (lime-stone dust) in extensive scale is used on exposed areas within the mines. For preventing roof collapse, steel bolting support is adopted.

The depth of Indian underground coal mines are generally confined to 250-300 metres. However, there are few mines like Sudamdih, Moonidih, Amlabad, Parbelia, Chinakuri, etc. which are operating between 400 - 700 metres depth.

By this method about 40% of underground coal can be mined and its cost of production is also high compared to opencast mine.

COAL PRODUCTION IN INDIA

Among coal producing countries India occupies third position, China and America occupy the first and second position respectively.

Coal Production In India - At a Glance

Year	Production	Year	Production (Million Tonnes)
1815-1823	400 t	1955-56	38.40
1832	14,000 t	1960-61	55.66
1846	91,000 t	1970-71	72.94
1850	0.12 mt	1972-73	77.83
1860	0.30 mt	1976-77	101.03
1870	1.02 mt	1980-81	114.01
1880	1.74 mt	1982-83	130.60
1900	6.12 mt	1990-91	211.73
1910	12.25 mt	1991-92	229.29
1920	17.09 mt	1992-93	240.84
1930	22.68 mt	1993-94	248.68
1940	29.85 mt	1994-95	257.77
1950	32.51 mt	1995-96	282.00
1951-52	34.40 mt	1997-98	295.80
		2000-01	313.64

t - tonnes

mt - million tonnes

India occupies third position in coal production in the world. The coal production in 1994-95 by leading countries has been stated in a table.

Coal Production by Leading Countries

1.	China	1154 mt
2.	USA	800 mt
3.	India	257 mt
4.	Russia	183 mt
5.	Australia	180 mt
6.	S. Africa	180 mt

Although Indians knew about the existence of coal and its usages since ancient times. However its production in commercial scale began around 1775 during British rule from a mine in Raniganj coalfield. Thereafter coal mining commenced in Daltongunj (1779), Giridih (1850), Mohpani (1862), Singrauli (1862), Warora (1871), Umaria (1882) and Jharia (1890) coalfields of India. To start with private companies were opened. And many small mines began producing small quantity of coal. Till 1823 the annual coal production was only 400 tonnes.

Most of the important coalfields of India were discovered by the end of 19th century, which almost coincided with the advent of steam-engine and its application in shipping, railway, power generation and other industrial use. Consequently the industrial activity began to increase, so the demand of coal started increasing day by day.

The history of Indian coal mining industry is directly linked with the discovery of new coalfields and consequently the development of Indian railways. The first train in India, drawn by a steam engine, had its run from Boribunder (Bombay) to Thana on 16.04.1853 and covered a distance of 32 k.m. This was the beginning of a new era in India. The first passenger train steamed out of Howrah station for Hoogly, a distance of about 38 k.m. on 15.07.1854.

On 3rd February 1855, the East Indian Railway started running trains upto Raniganj and their main target was to transport coal from the collieries operating in and around Raniganj. The opening of this train facilitated easy coal transportation, which otherwise was done by navigating through Damodar and Ajoy river. On account of this many new mines started opening in Raniganj coalfield and the

coal production also increased. At the same time with the discoveries of coalfields in other states of India, many new railway companies were being formed and a network of railways began spreading for coal transportation. Thus it can be said that coal mining in our country assumed the status of an industry on account of expanding Indian Railways.

By 1990, the coal production reached 6 million tonnes and the demand continued to increase. Many new mines were being opened or closed and new replacement mines opened. In earlier days mining was confined to shallow depth and in case some difficulty was encountered in a mine, it was abandoned in the same state. No one paid attention towards the safety of workers and maintenance of mines, nor anyone cared about it. Even mine maps were not prepared. This type of unscientific mining resulted in accidents like mine fire, explosions, inundation, etc. causing loss of life and valuable property. These accidents attracted the attention of British Government towards the coal industry.

As soon as the East India Company established its foot-hold in India it created a new department called "Survey of India" on 01.05.1767, purely on commercial considerations and it was assigned the task of preparing maps of the Indian territory held by the company, so that revenue collection and administrative management could be carried out efficiently.

In 19th century when coal gained importance the East India Company appointed Mr. D. H. Williams, a geologist of Geological Survey of Great Britain, in the departments of Survey of India as a Geological-Surveyor in 1846 and he was assigned the task of preparing geological maps of the then known Indian coalfields and to report their potential. Mr. Williams began his work from Raniganj coalfield in February 1846. He submitted his report in 1847 and with this began the era of scientific geological exploration in India.

On 13th January, 1851, the Geological Survey of India was established as an independent organization. For the first 50 years, this department's work was only confined to geological mapping of Indian coalfields. During these years, the Geological Survey of the

main Indian coalfields was completed. Thereafter, Geological Survey of India started paying attention towards the other aspects of Indian Geology.

By this time, coal production had picked up momentum. Accident rate in coal mines was rising and this compelled the British Government to pay attention towards this industry and an awareness started growing about the necessity of framing rules and regulations to run these mines under safe and planned conditions. Under this type of scenario, the then Government appointed Mr. James Grundi in Geological Survey of India as Inspecter of Mines in 1894. He was assigned the task of examining the working conditions prevailing in all mines and submit his recommendations for running the mines under safe conditions. In his report submitted to the Director, Geological Survey of India Mr. Grundi gave his suggestions, emphasizing the need to make rules and regulations for mine opening/running/management, inspection of mines, inquiry of accident, children's employment, medical facilities, and safety norms etc.

The British Government gave this assignment to a committee, which drafted rules and regulations for all types of mines working in India covering all spheres of mine activities, such as organizational management, upkeep, safety, compensation to accident effected worker, mine opening and closing, etc., and submitted its report to the Government for consideration and implementation on 19-12-1895. In 1897, in an accident in Kolar Gold field area, 52 lives were lost. Then in Khost Coalfield of Baluchistan (now in Pakistan) 47 lives were lost due to fire. On account of these accidents, the Government finalized the rules and regulations, and the first "Mines Safety Act" was introduced in India on 22-03-1901. An independent Indian Mine Safety Department was created on 07-01-1902 with its Head Office at Calcutta and later on it was shifted to Dhanbad in 1908, from where it functions today also. Thereafter, from time to time, Mines Safety Rules have been modified and new rules inacted, as per requirement.

By the first decade of 20th century the coal demand had

increased and also the coal production. The first Indian Steel Plant by Tata at Jamshedpur (01-04-1908) and the first world war pushed up the coal demand to an unprecedented level during the second decade and a matching coal production was achieved. By this time, in Raniganj and Jharia coalfields alone, 857 coal mines were operating. Out of this 288 mines were producing 1000 tonnes and 213 mines were producing 1000 to 5000 tonnes per month. Thereafter, demand fell down during the recession in third decade, to pick up once again during the second world war.

The credit of continuous growth of coal industry goes to the expansion of Indian Railways. In earlier days, the major portion of coal production was consumed for train movement. Since 1850, many new rail companies were formed and for running their trains, they opened up captive coalmines in Jharkhand, Orissa, Chhattisgarh Madhya Pradesh, Assam and Punjab. The railway traffic and goods transportation had increased considerably by 1905 and therefore to resolve disputes arising between the different Private Railway Companies and for better coordination, the Government of India created a new department called Railway Board. As per the resolution of the Indian Legislative Assembly in 1923, the Government decided to take over control of all Railway Companies in their own hand. The first Company to be taken over was East India Railway in January, 1925 and thereafter within a year all private railway companies were under the control of the Government and they were placed under Railway Board.

Coal Mining in Singareni coalfields of Andhra Pradesh was started in 1886 by a British Company called "Hyderabad (Deccan) Company Ltd.". In 1921 it was taken over by "Singareni Collieries Company Ltd." (SCCL) and since then this Company is producing coal in this coalfield. Later on during 1945, Nizam Government purchased all shares of this company from London market and took it under its control. Therefore SCCL has the unique distinction of being the first government controlled coal mining organization in India. Presently, it is jointly run by the Government of India and the Andhra Pradesh Government as a Public Sector Organization.

At the time of independence in 1947, the coal production in India was 22 million tonnes. A major part of this coal production was consumed by Indian Railways. According to "Indian Policy Resolution" adopted by Government of India in 1956, it was decided that right to open new coal mines would rest with Government and for this purpose the Government created a new Public Sector Organization called National Coal Department Corporation Ltd. (NCDC) on 05-09-1956 with its Head Office at Ranchi and the Management of 11 collieries of Railways was placed under it.

NCDC began its work on modern scientific lines and in course of time opened 30 new mines in Jharkhand, Orissa, Chhattisgarh, Madhya Pradesh and Maharashtra. In fact the credit of laying foundation of large scale open-cast mechanized coal mines in India goes to NCDC, which not only conceived such mega-project, but implemented them with outstanding success. The current 70% coal production in India comes from open-cast mines.

The annual production of the Railway collieries was 2.91 million tonnes when they were placed under NCDC in 1956. By 1973-74 the annual coal production of NCDC was 17 .44 million tonnes. By this time the annual coal production in India had reached 77.83 million tonnes.

Between 1910 to 1960, the Government of India had from time to time constituted many committees to find out actual working conditions of coal mines and for making recommendations for their safe management. All these committees had suggested some sort of government control to prevent unscientific slaughter of mining in National interest, so that loss of men and materials due to accidents are checked and a precious natural resource is conserved for future requirement.

But nationalization of coal industry could take place only in 1971 when Government of India assumed the control of coking coal mines through an ordinance on 16-10-1971. Thereafter these mines were nationalized on 01-05-1972 and put under the control of a new Public Sector Undertaking named Bharat Coking Coal Limited (BCCL) with its headquarters at Dhanbad. However, few captive mines of TISCO and IISCO (now under SAIL) were not taken over.

Coal seam outcroping in a nallha section.

Manual Coal Mining by unorganized sector in Moghalaya.

Belt conveyor system form an integral part of modern coal handling system.

Belt conveyor system in large open-cast mine.

A view of mined out coal.

Modern opencast equipment showing walking drag line in operation.

Subsequently, the control of non-coking coal mines was assumed by the Government through an ordinance on 30-01-1973 and these mines were nationalized on 01-05-1973 and put under the control of another new Public Sector Company called Coal Mines Authority Limited (CMAL) with its head quarters at Calcutta. This time also few captive coal mines belonging to TISCO and Damodar Valley Corporation (DVC) were not taken over.

At present, almost entire coal industry in India is under public sector enterprises, except few captive mines of TISCO.

Organizational Structure Of Indian Coal Industry

SL. NO.	COMPANY (H.Q.)	SUBSIDIARY COMPANY (H.Q.)	JURISD-ICTION	TASK	NO. OF MINES
I	COAL INDIA LTD. (Calcutta)	1) Eastern Coalfields Ltd. (Sanctoria)	Raniganj, Sahjuri & Rajmahal Coalfields	Production and Marketing	126
	A holding company and its mission is to produce the planned quantity of coal effici-	2) Bharat Coking Coal Ltd. (Dhanbad)	Jharia coalfield and few mines in Raniganj coalfield.	-do-	91
	ently and economically with due regard to safety, conservation and quality.	3) Central Coal-fields Ltd. (Ranchi)	Giridih, Ramgarh, East and West Bokaro, North & South Karanpura and Daltonganj coalfields.	-do-	54
	It directly supervises 5 mines in North-East region	4) Western Coal-fields Ltd. (Nagpur)	Mohpani, Kamptee, Tawa Valley, Umrer, Patherkhera and Pench-kanhan coalfields.	-do-	67

		5) Northern coal-fields Ltd. (Singrauli)	Hutar and Singrauli coalfields.	-do-	10
		6) South Eastern coalfields Ltd. (Bilaspur)	Sohagpur, korba, and Hasdo-Araud Coalfields.	-do-	75
		7) Mahanadi Coalfields Ltd. (Sambalpur)	Talcher and IB Valley Coalfields	-do-	22
		8) Cental Mine Planning & Design Institute Ltd. (Ranchi)	Regional Institute at Ranchi, Dhanbad, Asansol, Nagpur, Bubaneswar, Singrauli, Bilaspur and Tura.	Exploration, Mine planning/ Designing and Research.	-
II.	Singareni Collieries Ltd. (Kothagudem)	-	Godavari Valley Coalfields.	Production and Marketing.	33
III.	Steel Authority Ltd. (Delhi)	Raw Materials Division. (Calcutta)	In Jharia and Raniganj Coalfields	-do-	4
IV.	Damodar Valley Corporation (Calcutta)	-	East Bokaro Coalfield.	Production and Use	1
V.	TISCO (Jamshedpur)	Regional Offices in Dhanbad & Ghato-Taud	In West Bokaro & Jharia Coalfields.	-do-	6
VI.	J & K Minerals Ltd.	Public Sector Jammu	Kalakot Coalfield	Production and Marketing	2

Besides, some coal is mined in Meghalaya and other states from isolated pockets by other agencies.

In this process of nationalization, the new emerging organizational set-up was so developed that BCCL and CMAL began functioning under two separate departments, Government of India BCCL under Steel Department and CMAL under Coal Department. This dual control over coal production and marketing at times produced discordant notes and to resolve these practical difficulties the Government of India created a holding Company called "Coal India Limited" (CIL) on 01-11-1975 by amalgamating these two organizations with its head office at Calcutta to achieve better coordination and functioning, and also to take care of future perspective planning, so that new coal mining projects are conceived with adequate geotechnical support and required production of coal is achieved in time.

Besides, almost all coal deposits of Meghalaya, Nagaland and Mikir Hills of Assam are being exploited by manual mining in the unorganized sector. In 2000-2001 it was estimated that these mines in unorganized sector in Meghalaya produced about 4.07 million tonnes of coal. The Meghalaya coals find their way to distant places in Haryana, Himachal Pradesh, Punjab, Rajasthan, etc. In 1991, the CMPDI opened a small Regional Institute at Tura in Meghalaya to provide technical assistance to this unorganized mining sector.

The production statistics of the above mines are presented below: —

Sl. No.	Company	Production (In Million Tonnes)		
		92-93	93-94	94-95
1.	Coal India Limited	211.462	216.099	223.347
2.	Singareni Collieries Limited	22.511	25.279	25.648
3.	Steel Authority of India Limited	0.774	0.715	1.040
4.	Damodar Valley Corporation	0.077	0.065	0.285
5.	TISCO	3.742	3.964	4.163
6.	J and K Minerals Limited	0.012	0.022	0.021
7.	Meghalaya	2.340	2.543	3.266
	Grand Total	240.848	248.687	257.770

However, in recent years, the liberalized economic polices of the Government of India has opened the door for private sector participation in the field of basic infrastructure development, like energy, telecom, express highways, mining etc. This has attracted many foreign and Indian companies to invest in energy sector for building thermal plants of different capacity at various locations in India. The Government have given clearance to some of the projects and the companies have been given mining blocks also for developing captive coal mines, to meet their coal requirement for running their plants. A table below states details about this projects.

Sl. No.	Company	Proposed Plant (Capacity)	Coal-field	Alloted Block	Reserves (Million Tonne)
1.	R. P. Goenka Group	Buj-Buj (2×250 MW)	Raniganj	Sarishatali	150
2.	Kalinga Power Corp.	Dhiburi (2×250 MW)	Talcher	Utkal - 1	200
3.	Nippon Denro	Umrer (4×250 MW)	Wardha Valley	Bander, Baranj, East Lohara	296

These Companies have started mine planning and designing work for the blocks allotted to them. The proposals of many other companies are at various stages of consideration, where captive coal mines will be developed by the allottee company itself. Alternatively it is also being considered that CIL subsidiary may open dedicated mines for use of the company allowed to set-up a thermal plant.

ENERGY RESOURCES

In Indian energy scene, coal occupies dominant place,banning nuclear,other indigenous resources, cannot take its place.

At the time of independence (1947), India had an established capacity of producing 1300 MW electricity and its distribution was restricted to few metropolitan cities of India. However, as a result of planned development during last 50 years, this capacity is now increased upto 96,266 MW during January 2000 and its benefit is enjoyed by all Indian cities and also 85% villages.

Electricity Providers in India

January-2000

Public Sector		
Central	-	30.20%
States	-	61.05%
Private Sector		8.75%
Total	-	100.00

The future energy needs are quantified on the basis of assessment of likely increase in population and the commensurating requirement of agricultural input, electricity consumption, expanding transport system, industrial needs, etc. Once the energy targets are fixed, the resource potential available are reviewed and as assessment made of the extent, they can be utilized. After completing this exercise, other alternatives are decided to meet the projected target.

In 70's, the average increase in Indian GDP was 3.6%. However, it increased to 5.6% during 80's and it is expected that in coming years also, this growth rate is likely to continue.

Electricity demand in India has been growing on an average, at about 9-10% per annum. As per present indications, the additional capacity requirement in the economy, in the next 20 years may be around 2,00,000 MW, so that Indian economy could sustain the expected growth rate of 5.6% per annum. It is a difficult task and would need very heavy investment.

The two third of India's current energy requirement is met mainly by six commercial sources, i.e., coal, lignite, oil, natural gas, hydel and atomic. The rest of the one-third requirement is met through noncommercial sources like - fuel, wood, agro residue, animal waste, etc.

In recent years, efforts are being made in India to harness other non-conventional renewable energy resources like wind, solar, geothermal, industrial waste, etc. but their contribution so far is very small. According to a survey report, India has vast potential of such resources, which are tabulated below:—

Sources / Technology	Approx. Potential Availability
Bio Gas	12 Million Nos.
Bio Mass	17,000 MW
High Efficiency Wood Stove	120 Million Nos.
Solar Energy	5×10^{15} WHr/Year
Small Hydro	10,000 MW
Wind Energy	20,000 MW
Ocean Thermal	50,000 MW
Sea Wave Power	20,000 MW
Tidal Power	9,000 MW
Urban & Industrial Waste	1,000 MW
Geothermal Energy	10,000 MW

The status of the main energy resources of India is described in the following paragraphs.

1. Atomic

Uranium and thorium are the two primary source of atomic energy. Unlike coal/lignite, they do not occur independently, but have to be recovered by processing their ores.

Upto 1993, mineable uranium deposits in India were present in Jharkhand, Madhya Pradesh, Meghalaya and Rajasthan. Reports say there is 66,360 metric tonne of uranium (U_3O_8) reserves, in India.

However, in 1998, the Atomic Mineral Division (AMD) of Atomic Energy Department discovered large resources of rich uranium in the Bhima basin at Gogi in Gulbarga district of Karnataka. These reserves contain more than 0.1% uranium-oxide which has the highest recorded value out side Canada, where richest grade uranium is found in the world. Earlier to this discovery, AMD had reported discovery of new uranium deposits in Tambapura - Yelapur region of Nalgonda district in Andhra Pradesh. The uranium reserves established in this region are much more, compared to Singbhum Belt in Jharkhand, where India's three uranium mines- Jaduguda, Bhatin and Narvapahar are in operation.

The main source of obtaining thorium is monazite. The Indian coastline is about 5500 km long, stretching in the west up to Pakistan and in the east up to Bangladesh. Within this long coast line, where ever sand beaches are found, they contain reserves of monazite. These deposits contain 8% to 10% ThO_2, which is higher than other world deposits. Besides these sand beaches, deposits of monazite are found in inland areas of West Bengal and Tamil Nadu also.

India has the largest reserves of monazite in the world, estimated (1993) around 5.05 million tonnes (containing 0.45 m. tonnes of ThO_2).

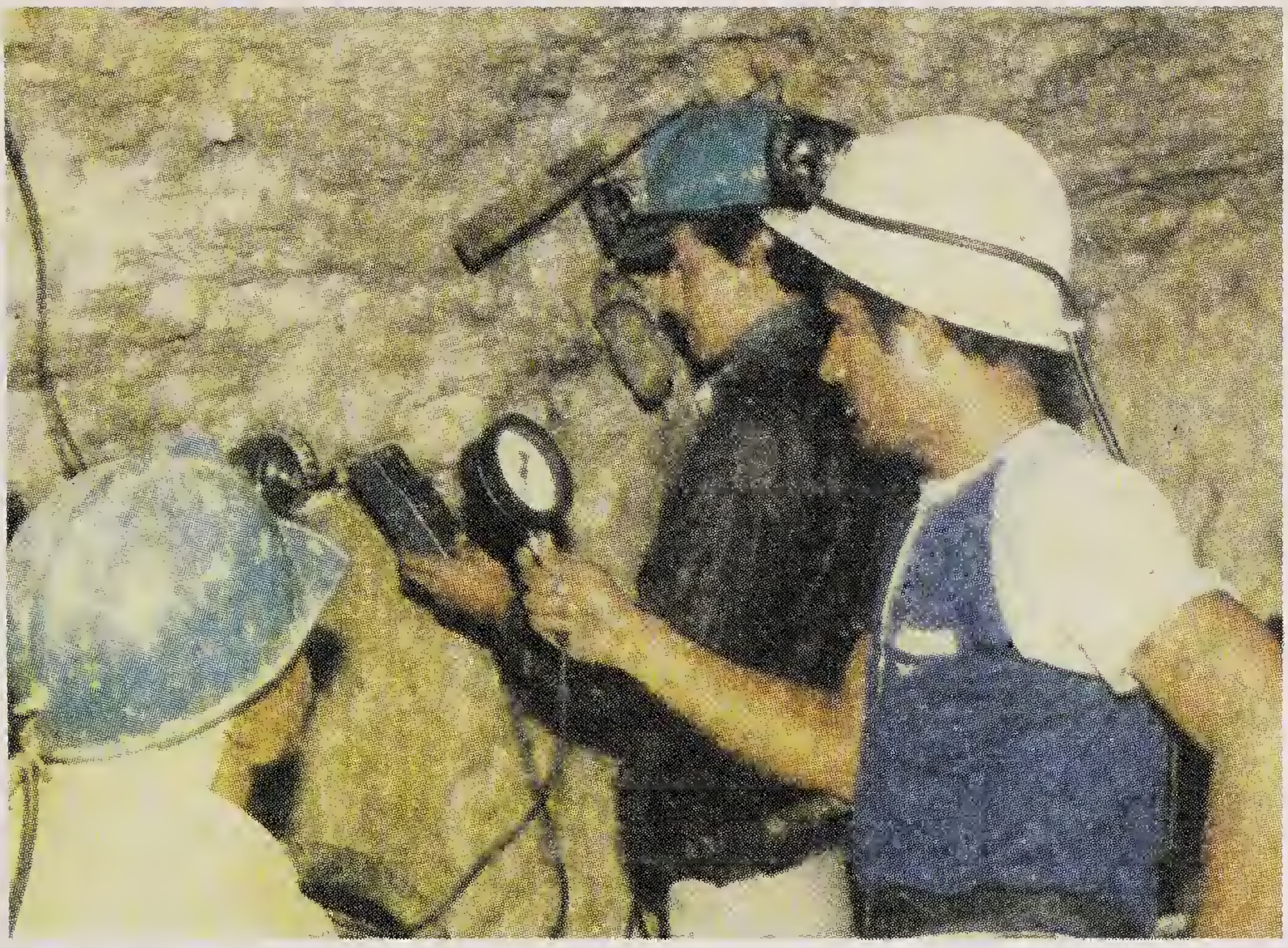
As on March 31, 1994 six nuclear power stations were on commercial operation in India: Tarapur (Maharashtra), Rowatbhata (Rajasthan), Kalpakkam(Tamil Nadu), Narora (Uttar Pradesh), Kakrapar (Gujarat) and Kaiga(Karnataka). Their total installed capacity is 2880 MW. The Nuclear Power Corporation of India has a programme of building 10,000 MW electricity generation capacity by the end of the year 2004-2005 within the country and further expansion to 20,000 MW by the year 2020.

Region	Nuclear Generation Capacity (MW)
1. Northern	3615
2. Western	2920
3. Southern	3465
4. Eastern + North-east	-
All India	10,000

Although the cost of construction of a nuclear power station is higher than a thermal and hydel plant, but once the nuclear plant is in operation, the electricity produced by it is the cheapest, since no recurring cost is involved. Besides, it produces no environmental pollution and the resulting rehabilitation problem of displaced persons is also comparatively very small.

But still, most of us are concerned about the two safety hazards namely fear of radiation exposure and disposal of waste generated by nuclear power plant. Now everybody knows that radiation from a nuclear plant in public domain during its normal operation is only a negligible fraction of natural background radiation to which we are exposed to anywhere or everywhere. The reason for this is, unparallel concern for safety, the supermost consideration kept in mind during the design and construction and operation of a nuclear plant. During last 45 years, India's nuclear reactor operating has been free from any incident leading to release of radioactivity into the environment. Today, India's nuclear power programme is at a mature state. It is not only confined to development of indigenous technology, but a vast infrastructural base has been created and developed for its support.

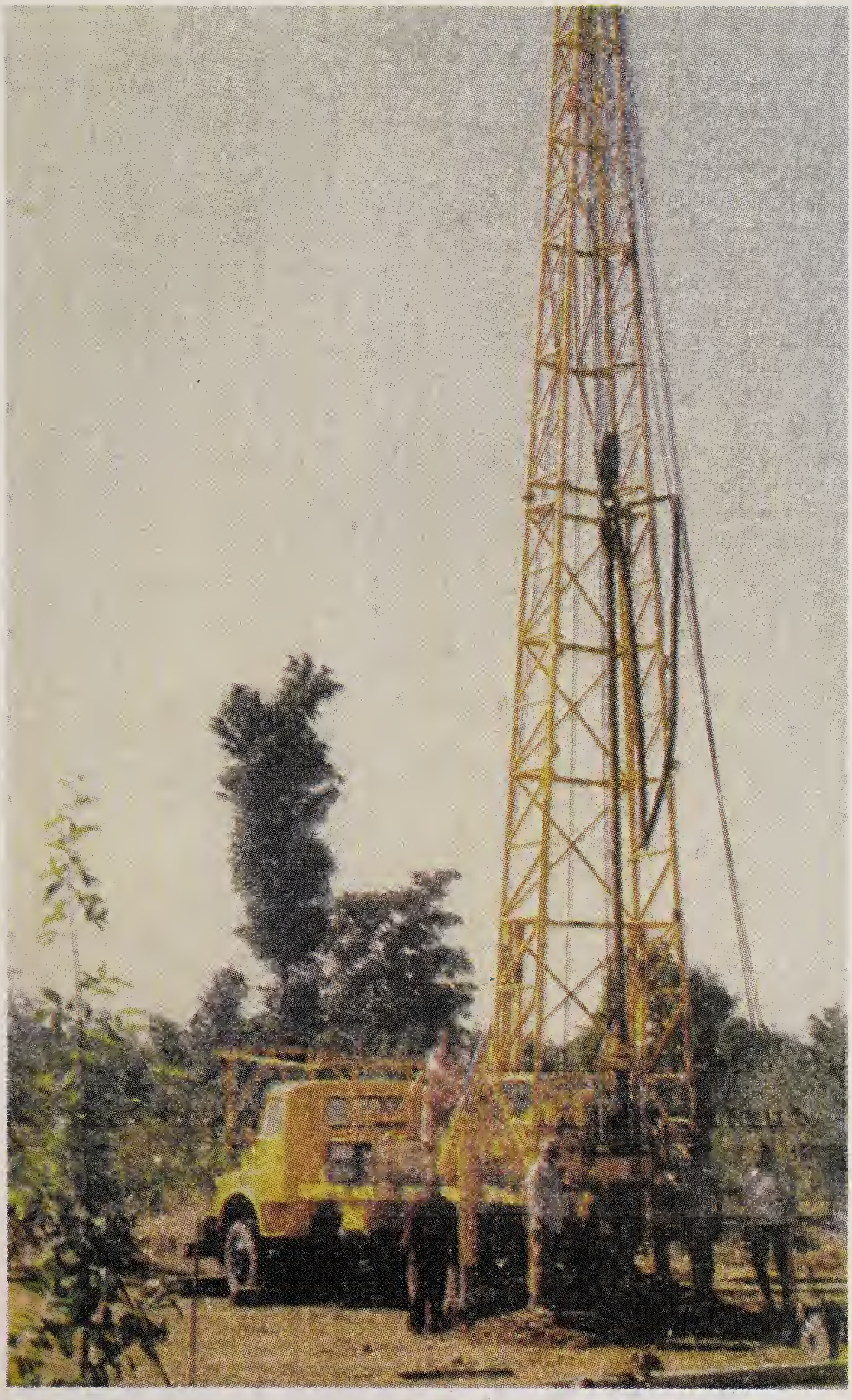
India's nuclear scientists say that nuclear power generation is now safe. But despite such achievements, due to lack of foresight and geopolitical compulsions, its contribution towards total electricity generation in India is only 2.6 percent, as against 22-76 percent by the advance countries. Infact it is the only indegenous resource which can meet India's entire growing power demand single handedly.



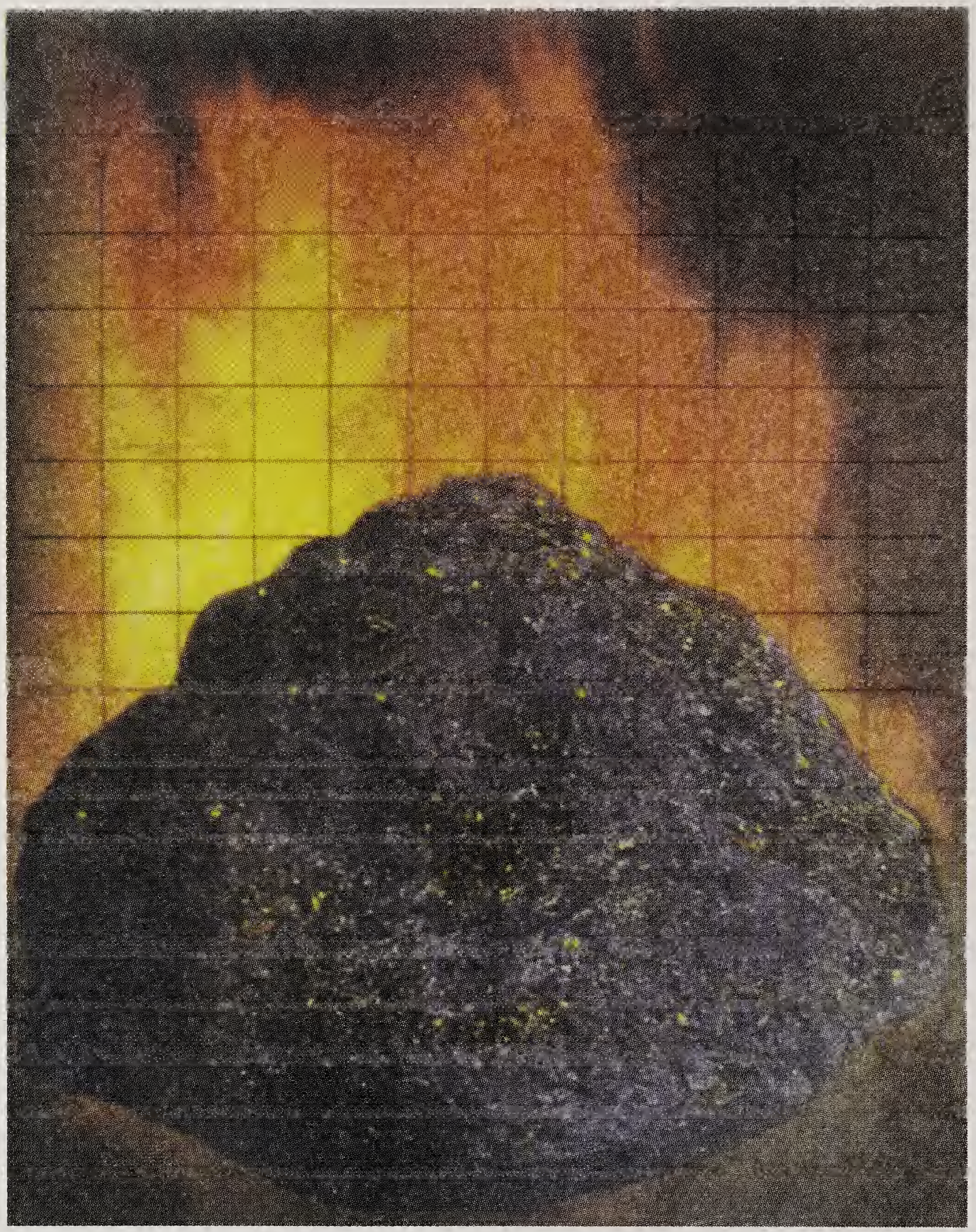
Environment monitoring in underground mine.

Modern opencast equipment showing shovel-dumper in operation.

Coal Handling Plant : Rapid coal loading system.



A drilling site for coal exploration in Kothagudem, Singareni coalfield, Andhra Pradesh.



Coal Block-An Artist's Impression.

2. Hydel

Hydro energy represents the kinetic energy associated with a mass of moving water. The water movement can be either vertical (water fall) or horizontal (flowing water in plains). The mechanical energy produced from both these movements is called hydro energy.

As per estimates of March 1992, the Indian River Baisns have a total potential of producing 84,044 MW of hydel power on commercial scale at 60% load factor.

The data above clearly shows that India has vast potential for hydel power, but its regional distribution is very uneven where northern region has 75% and southern region has 25%.

Besides, a major part of its potential in northern region is located in the Himalayas, which are geologically unstable and very sensitive to earthquakes. Realizing this important fact, most of the hydel projects in this region have been constructed in their foot hills. Thus the major hydel development work in India has been largely confined to geologically stable Deccan peninsula.

As per January 2000 data, India has developed 23627 MW Hydel energy projects, which is 25% of its total capacity. Therefore, India can derive much more advantage by harnessing this natural resource.

However, to take its full advantage we will have to proceed very carefully, because despite being very beneficial the Hydel projects are instrumental in creating many social and political unrest for which we have not been able to find right solution in independent India, specially the rehabilitation of displaced person and the recovery of lost flora and fauna. On account of these two reasons only, the two major important projects, Tehari and Narbada, are half way held up due to disputes and agitations, even after the Government has spent several crores of rupees. The distribution of dam water also generates disputes between neighboring countries and within the country among neighboring states, and decades pass in resolving the disputes.

Therefore, to take full advantage of this natural resource we

have to judicially think in new terms for its utilization by incurring minimum loss. The solution lies in construction of micro-hydel projects. Since last 10 years government has started taking interest in this direction and many such plants have been constructed and many more are under construction.

3. Oil and Natural Gas

Oil and natural Gas are generally found together inside the earth-crude oil at the bottom and gas at the top. But in some reservoirs only gas reserves are found. The gas reservoirs also may be of different types, e.g. mixed with water and crude oil, in liquid condition or as free gas reserves.

About 600 sedimentary basins with potential for oil and/or gas are known to exist world wide. However, with the current technical know-how available, it is not possible to recover oil and gas from all the fields commercially . But, based on experience gained, it can be said that with the improvement in recovery techniques, these uneconomic reservoirs of today will become profitable in future.

Production of oil and gas through borewell is not the end of it. They need refining to produce the consumable product.

Most of the Natural Gas reservoirs are found under high pressure. Therefore, as soon as the drilling pipe enters the gas reservoir, the gas gushes through drill pipes to surface and in the process a large part of it is wasted. Very often it has to be flared or alternative arrangements are made to reduce its production till storage and pipeline distribution facility are established.

The discovery of oil in India can be indirectly attributed to the coal industry. Coal mining in Makum coalfield of Assam was commenced in the year 1882. In order to develop this coalfield, when a railway track was being laid by "Assam Railway and Trading Company" between Ledo and Dibrugarh in 1889, the first oil occurrence in India was accidentally discovered near Digboi (which was then a small village). The story goes like this:—

"One day the engineer in-charge of the railway company noticed a black greasy substance smeared on the legs of the

elephants being used for various jobs. Out of sheer curiosity, he followed the elephant tracks and his search ended in a pond full of crude oil near Digboi village".

This was an important discovery and based on this began search for oil and natural gas in India on scientific basis. Assam Oil Company was established in 1899 and it has the distinction of being the first oil producing company of India.

While oil and natural gas can occur in rocks of any geological age from Cambrian to Pliocene, in India their reservoirs are mainly occurring in Tertiary rocks. The total area of India is 3,287,263 sq. km, within which about 26 tertiary basins (sedimentary) have been identified. These basins are spread over in 1,780,000 sq.km area, out of which 380,000 sq.km lie under water in continental shelves.

One estimate puts the prognosticated reserves in these 26 Indian basins at a little over 21 billion tonnes of oil and oil equivalent of gas. But so far commercial production is confined to Assam, Gujarat and Bombay High reservoirs. However, at many production points gas has to be flared for two accounts,

a) due to lack of infrastructural facilities for gas distribution from Bombay High and
b) due to lack of demand in North-east region.

On the other hand, it is not possible to produce the entire estimated reserves under the present technical know how. In Indian context the critical Reserve/Production (R/P) ratio is enumerated below:—

Sl.No.	Region	Reserve : Production 1996-97	1989-90
1.	Cambay	25:1	10:1
2.	Assam	32:1	13:1
3.	Bombay High	22:1	15:1

But, with the improvement in recovery techniques R/P ratio increase. Therefore, there is always a possibility of increased recovery from these in future.

It has been observed till the year 1992 our oil and natural gas

reserves had been increasing, but subsequently they are getting reduced. The main reason for this reduction is the shortage of investment in this sector.

During the year 1950 India had produced 0.5 million tonne of crude oil, which increased to 34 million tonnes in the year 1989. Thereafter there was some reduction in production. Although crude oil production has been declining after the year 1990-91, the natural gas production is continuously increasing. The reason for this is that the petroliferous basins of India are considered as good prospects for natural gas. Most of the recent hydrocarbon discoveries in India indicate presence of huge quantities of associated gas, may it be Tripura, Kavery, Tapti basin, etc.

Although gross natural gas production was about 18 bm^3 in 1993-94, net production was 16.3 bm^3. This was also possible, when only 10% gas was flared during 1993-94 as against 40% during 1980's. As a percentage of gross production, net production has increased during the past decade, but flaring has not been eliminated. This is due to several reasons; the delays in commissioning downstream gas utilization facilities being one of them. Moreover, while producing oil from a reservoir having associated gas, the production of gas cannot be stopped. Therefore, to reduce/stop flaring of gas, either the production of oil has to be curtailed or stopped - which is not in the interest of India. This would increase our oil impart bill. Keeping this in view it is very essential to develop downstream pipe line distribution network from oil producing centres so that valuable natural gas resources is fruitfully utilized instead of flaring. By implementing this we will be able to save some foreign exchange as well.

In India, the consumption of petroleum products increased form 17.9 mt in 1970/71 to 60.7 mt in 1993-94. According to current estimates the demand of petroleum products by 2010-11 may reach upto 165mt.

The problem of India is how to meet this type of growing demand. The current estimates of our recoverable petroleum reserves and the current production status is shown below:—

Product	Year 1994	
	Proved Recoverable Reserves	Total Production
Crude Oil (Million Tonne)	764.6	27.02
Natural Gas (Billion Cubic Metre)	706.7	18.33

As per above table if we maintain a production level of crude oil at the rate of 30mt per year, our reserves will last for another 24 years. In case we increase this level of production, these reserves will have a much shorter life.

Therefore, looking into this situation, we have to understand that India has to impart crude oil on regular basis. In order to reduce this import we will have to increase natural gas production and consumption. This is possible only when we are able to organize proper infrastructure for gas storage, distribution through pipe-line to consumer in the country. The increase in natural gas production and its utilization will also reduce the offtake of crude oil in industrial sector. On the other hand production of crude oil could be increased from reservoirs containing oil and associated gas. Besides we will have to introduce Enhance Oil Recovery techniques in old and progressively diminishing reservoirs to increase crude oil production. But this requires very heavy investment. According to one estimate India will have to spend about 150 billion American dollars in coming 10-15 years to meet its demand in 21st century.

In fact India is a net oil importing country. With the spate of development activities in the country the demand of petroleum products began increasing in 1980's which has acquired galloping pace in 1990's and on account of this country's oil import bill is increasing at an unusal speed. As per the statistics of 1995-96, India spent about 30% of its total income (from all sources) for importing petroleum products.

The review of above facts clearly demonstrate that to achieve self-sufficiency in the field of energy, the Indian oil and natural gas reserves can play only a small but important role.

4. Coal

In India, coal is the most important fossil fuel and a source of energy for generating electricity. The main reason for this is its easy availability and relative abundance compared to the oil and natural gas reserves.

As per 1.1. 2002 estimates India has about 234 billion tonnes of coal reserves upto 1200 metre depth:—

Indian Coal Reserves Upto 1200m Depth (1.1.2002)
(In Million Tonne)

Distribution	Exploration Status			Total
	Proved	Indicated	Inferred	
Coking	16390.20	13,333.89	2088.09	31812.17
Non-coking	70497.65	95937.72	34959.79	201395.16
N.E. Region	431.79	106.39	368.77	906.95
Grand Total	87319.64	1,09377.99	37416.65	234114.28
Percentage	37	47	16	100

87% of these reserves are found within 600 metre depth

The proved and indicated category of coal reserves are generally considered authentic for coal mining. Then progressive exploration continuously upgrade the reserves, say from inferred to indicated or indicated to proved. As per geological evidences noticed, the exploration work in coming years may add another 100 billion tonnes to the Indian coal reserves. Therefore, it will not be illogical to assume that India has 200 billion tonnes of mineable coal reserves, a solid foundation, over which we can plan and open new projects for additional coal production as per projected demand of future.

In the year 2000-2001 India produced 313 million tonnes coal. After the nationalization of coal industry in India, the coal production has increased very fast. Therefore, if we develop our future projections on the basis of this increasing trend achieved during past nationalization period we find that it may be possible to produce 1000 million tonnes by 2011. However, this level of production is not

likely to be achieved due to infrastructural, transportational, technological, environmental and other constraints.

Assuming that the production level of 500 million tonnes can be maintained and will not be constrained by above mentioned factors, there is a possibility of reaching this level of production by 2010 and this would be according to our coal requirement.

Like oil and natural gas, all the coal reserves cannot be recovered by mining. As a broad generalization, only about 505 coal reserves are likely to be mineable due to the existing mining technologies, mining regulations, environmental liabilities, etc. Taking all these factors and the experience of past together, it is seen that 4 tonnes of coal reserves can yield, in general, a production of 1 tonne of coal. This then is the critical Reserve/Production (R/P) ratio. This means that ciritcal R/P ratio for coal is 4:1. It also means that only one-fourth of the coal reserve can be recovered by mining.

Therefore, 200 billion tonnes of India's coal reserves can sustain an annual production level of 500 million tonnes in coming 100 years.

A 10,000 MW thermal plant needs about 40 million tonnes of coal annually. Now, if out of this 500 million tonnes annual coal production we earmark 400 million tonnes for thermal generation, it will produce 1,00,000 MW of electricity annually, which will be sufficient to meet our requirement.

However, for achieving the above goal we have to make heavy investment in this sector. Under the current price structure 1MW of thermal generation requires an investment of rupees four crores. The magnitude of investment needed in this sector can be well calculated from these data.

Indian coals have one great deficiencies - high ash content. Now since coal is a gift of nature to the mankind, it should be also understood that high ash content of Indian coal is also a natural phenomenon over which we have no control- but why?

The transformation of vegetal matter into peat is the first stage in coalification series and during the process* of peat forma-

*(according to one study 1 metre peat formation takes 500 to 600 years in Tropical regions and about 1500 to 1700 years in cold temperate regions)

tion important quality characteristics are incorporated which determine the ultimate coal composition. The formation of peat requires delicate balance between the rate of subsidence and rate of built of plant materials to form peat. This in turn is related to water and nutrient supply which are controlled by climate and physiography. Both of these factors, in turn influence the supply of epiclastic sediments which lead to fixation of the amount and type of ash in ultimate coal. From this point of view the palaeo-climatic environment at the time of peat formation is very important.

The high ash content in Indian coals indicate that during the process of peat formation, it had to suffer oxidation i.e., accumulated vegetal matter was not always completely submerged in water. Exposure of peat bog to atmosphere lead to deposition of silt, fine clay, silica and other non-combustible matter at the top. This process was repeated time and again, during the accumulation of peat bog. Sometime such pauses were of long duration, which lead to the deposition of mineral charcoal at the top of the bog and this, when intermingled with the above mentioned non-combustible material formed a thin layer and its presence has increased the ash content in coal.

As against this, in the Gondwana coal fields of Australia and New Zealand the peat accumulation went un-interrupted under water submerged conditions. Therefore coal from these countries have much less ash content.

Besides high ash content, another speciality of Indian coal is presence of thick coal seams. The coal seams found in Raniganj, Rajmahal, East and West Bokaro, North and South Karaupura, Korba, Singrauli, Ib Valley and Talcher coalfields are very thick-20 to 40 metres. In these thick seams many dirt bands are present and these also downgrade the coal quality. The reason for this is that these bands are mostly carbonaceous and like coal has crumbling tendencies and they cannot be separated in course of coal mining.

Whereas coal seams from other developed countries are thin, having low ash and devoid of carbonaceous bands. Therefore during mining operations their is possibility of only non-carbonaceous

material mixing with mines coal, which can be easily picked and removed.

In India, both coking and non-coking coal reserves are found. Based on their quality characteristic the following thumbrule has been practiced for the construction of thermal and steel plants.

Industry	Rank	Ash%
Steel	Coking	17
Thermal Power	Non-coking	35

The foundation of almost all steel and thermal plants constructed in India till 1970's are based on above consideration. However, due to shortage of low ash coal reserves and construction of new plants, on account of which demand has increased manifold, high ash coal needs washing for its proper usage.

But the washing characteristics of Indian coals is bit difficult and on account of which cost of production of desired level ash for specific industries also increase. In India, 24 coal washeries are under operation and barring one all the washeries are constructed to wash coking coal meant for steel sector. Besides, majority (15) of these washeries were constructed in 1950's - 1060's and they were designed to wash low ash easy washing coals then available for mining.

However, after nationalization (1971-73), with the introduction of mechanization in the underground mines and opening of large scale opencast mines the total coal production has substantially increased, but the coal quality has suffered since dirt bands are difficult to be removed in such mechanized mines. This has directly affected the performance of coking coal washeries. All these washeries are designed to produce 17% ash coal, but now on account of high ash coal and non-availability of right product mix, they are now producing 22% to 24% ash coal. This is the reason, the Indian Steel industry is importing low ash (6% to 10%) coking coal, in order to mix it with high ash Indian coal for making designed compatible coke for their blast furnaces. This is very essential, because each unit increase of ash in coke results in 2.5% fall in capacity utilization of blast furnace.

In 1995-96 India produced 16.48 million tonnes of coking coal (including washed coal), when the steel industry requirement was 26.03 million tonnes. This short-fall was met by importing low ash (10% or less) coking coal from Australia and New Zealand.

Till 1980-81, the gap between demand and availability was insignificant. Thereafter, several more new plants have been constructed and this gap has started widening. Currently we are importing about 10.5 million tonnes of coking coal. In 1995-96 the cost of coking coal imported from Australia was 50 American dollars per tonne.

Currently, 70% of the coal production in India is of low grade having 40% to 50% ash. In coming years, with the increase in production, the low grade coal contribution is expected to increase from 70% to 80%. Therefore, it is essential that all types of non-coking coals are compulsory washed to prepare specific industry-wise ash level coal, so that we are able to derive maximum advantage of this valuable natural resource.

In India, the thermal plants are the biggest user (60%) of coal. Initially most of the power plants were designed to use 35% ash coal. But with the introduction of mechanization in Indian mines, the ash level has increased in mined coal. This coupled with substantial reduction in availability of low ash coal reserves, India is left with no other alternative but to mine and use high ash coal.

Keeping above facts in view, the boiler design of new thermal plants constructed after 1970 are being made to use 40% to 50% ash non-coking coal. In the process the size of the boiler has also increased compared to the boiler for using 35% ash coal and this has increased their manufacture cost as well. Now to off-set the increased cost most of the new thermal plants are now been constructed near the coal mine, i.e., pit head power plants are the order of the day.

In India, power plants use unwashed coal, and the quality of their feed is also changing and it is never the same. Despite this quality variations their performance in general is satisfactory. Some of them have achieved plant load factor as high as 83% utilizing high ash coal.

But this doesn't reduce the importance of washing coal. It is beyond doubt that if tailor-made industry specific washed coal are prepared and used accordingly, the industries concerned will be benefitted in many ways. Their performance and production will improve, and environmental pollution will also be reduced. Besides coal-dust injection in blast furnace for steel making would pave the way of non-coking Indian coal.

From environment point of view we find that in spite of having high ash and low calorific value the Indian coal is eco-friendly because it contains some very positive features. For example - compared to the coal reserves of other countries, Indian coal contains less sulphur, phosphorous and toxic elements, which contribute maximum pollution from coal.

Therefore, if Indian coals are systematically washed to produce coal at different ash level, it will have great demand in environment conscious countries of the world for mixing it with their low ash-high sulphur coal to maintain environment balance.

The above facts clearly demonstrate the necessity of washing all type of Indian coals before using them. Coal washing in India has to be given priority on war footing, so as to get maximum advantage of the valuable gift of nature.

COAL - PRIME SOURCE OF COMMERCIAL ENERGY

If India wants self-reliance in energy fields,It has no other option, but to rely on its coal fields. In India, Coal has been the prime source of commercial energy, followed by oil/gas (one third of which is imported), hydroelectricity and marginally atomic power. The hydel option is costly and unfriendly to environment. The known hydrocarbon reserves in India are limited, that may last few decades. However, the nuclear option has full capacity to meet India's total energy requirement single handedly, but for geopolitical considerations India has not been able to take its full advantage. As against these, substantial coal reserves have been established in Indian coalfields, that can sustain an annual coal production of 500 million tonnes for next hundred years. In 2000-01, the coal production in India was 313 million tonnes.

Now, since Indian coals are blessed by the nature to contain high ash, we have to compulsorily wash our coking and non-coking coals to utilize their maximum heat value content. On the other hand, it has also to be understood that for our existing and upcoming steal plants, we will have to continue importing low-ash coking coal, since there is acute shortage of such quality coal in India. However, this valuable foreign exchange drain can be minimized by judicious application of "Coal Dust Injection" in currently operating plants and the construction of new plants based on "Corex Process", in both of which low-ash non-coking coals are utilized. Steel Authority of India (SAIL) has already initiated steps in this direction since 1998. Thus it would be in national interest to wash non-coking coals as well.

Compulsory washing of Indian coals prior to their end use, would also insure all-round economic benefits, such as — reduction in coal transportation cost (due to removal of unwanted ash), improvement in boiler efficiency would increase production and plant load factor along with reduction in specific coal consumption, open the door for introduction of low cost smaller size boilers, reduction in pollution emission, etc. Besides, rich environment conscious countries may start showing interest in purchasing this low ash Indian coals which have comparative eco-friendly characteristics.

Keeping these in view, the Government of India has issued a new set of directives in 1997-98 that all power plants located beyond 1000 kms distance from coal mine will use washed coal at 34 percent ash level w.e.f. 1.6.2001. Use of washed coal; has also been made mandatory in non-pit head power plants in urban centres. This is a sound policy decision, but would call for massive non-coking coal washing programme without further delay, so that we derive maximum advantage of this "Mr Dependable" indigenous resource.

However, the indegenous coal cannot meet the total energy demand in India. There would remain a shortfall of about 40 percent, which has to be met by using other energy resources like nuclear and non-conventional. Therefore, India has to reconsider its nuclear option, which according to Indian scientists as now become a safe proposition. Along with this, India has to press its full throttle in utilizing the solar, wind and biomass energy potential, in which India is not only very rich, but is also a fore-runner in its utilization in the world today.

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